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Holy Ganga and the mighty Amazon

by

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Abstract

River Ganga is the largest and most sacred river of India. As compared to the mighty Amazon, it is very small but exerts great influence on the socio-cultural life and economy of India. Though the basin of River Ganga has been the cradle of human civilisation for several millennia, the rapid growth of human population, coupled with urbanisation, intensive agriculture and industrialization, has resulted in rapid deterioration of water quality and loss of aquatic biodiversity during past few decades. Some salient features of River Ganga are presented here and compared with those of River Amazon, in tribute to Professor Sioli who pioneered studies along the "Rio Amazonas".

Keywords: **Ganga River, Amazon River, Limnology, Amazonia, Neotropics.**

Resumo

O Ganges é o maior e mais sagrado rio da India. É bastante pequeno quando comparado ao majestoso Amazonas, mas exerce uma grande influência na vida sócio-cultural e na economia da India. Mesmo tendo sido o berço da civilização humana por milênios, a bacia do Rio Ganges tem sofrido uma grande deteriorização nas últimas décadas na qualidade da água e na biodiversidade aquática, em conseqüencia ao rápido crescimento da população, acoplado à urbanização, agricultura intensa e industrialização da área. Como tributo ao Professor Sioli, que foi um pioneiro em questões referentes ao Rio Amazonas, características importantes dó Rio Ganges serão apresentadas e comparadas com as do Rio Amazonas.

*Dedicated to Prof. Dr. Harald Sioli on the occasion of his 90th anniversary.

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Introduction

As a young student, I was introduced to Brazil as the home of the rubber plant (*Hevea brasiliensis*) and the world's second longest river, the Amazon, and as the land of extensive pristine tropical rainforests. In mid-1960s, when I started learning ecology, I got interested in two exotic aquatic plants, of which one (waterhyacinth, *Eichhornia crassipes*) had already become a noxious weed throughout India and the other (*Salvinia molesta*; then identified as *Salvinia auriculata*) had just become a problem in a reservoir in Kerala (south India). I learned that both weeds were native of Brazil. I became curious to learn more about the country with which India's affinities date back to the period of Gondwanaland. Soon, at the International Symposium on Tropical Ecology (Varanasi, January 1967), I met Professor Harald Sioli whose lecture on the River Amazon, with numerous slides, provided me the first impressions of the mighty river which discharged billions of cubic meters of water into the Atlantic Ocean. At the closing session of the same symposium, Prof. Sioli spoke at length on the ecology of human cultures and dealt with the impacts of materialistic western culture on the Earth's environment (SIOLI 1968). My admiration for Professor Sioli was instantaneous and it grew with time as I learned more about him, his work and Amazonia. At that time when environment was still not a matter of concern, only a person like Professor Sioli, who had spent most of his life in nearly pristine environments exploring the River Amazon and had also witnessed the changing world for several decades, could have indeed appreciated the beauty of nature and the differences in human cultures. During the past 33 years, I have had the privilege of interacting closely with Professor Sioli in many conferences and during my frequent and extended visits to the Max-Planck-Institute for Limnology in Plön (of which he had been the Director during 1959-80).

Prof. Sioli has been greatly concerned at the rapid deterioration of the environment throughout the world, particularly at the loss of social and cultural diversity with the economic development and globalisation leading towards a homogeneous world with similar anthropogenic landscapes dominated by concrete jungles, and similar cultures and life styles. All natural and anthropogenic changes in the landscape are mirrored in the lakes and rivers, and therefore a limnologist is in the best position to look dispassionately at the entire landscape and its spatio-temporal dynamics. Our understanding of the River Amazon owes most to the pioneering work of Professor Sioli. These studies have been admirably continued by his students and colleagues who pay tribute, through this special volume of AMAZONIANA, to its founder Professor Sioli on the occasion of his completing 90 years of fruitful life dedicated to Amazonia, limnology and tropical ecology. I deem it a great privilege to join my friends in honoring him.

As I think of the mighty Amazon of which I had only a glimpse, my thoughts return to our own River Ganga. River Ganga is no match to R. Amazon whose drainage basin covers an area more than two times that of India. However, when R. Amazon was discovered in 1542, several decades after the discovery of the New World (SIOLI 1984), the basin of R. Ganga had already been transformed by the humans over more than five millennia. Yet until less than a century ago the water quality in R. Ganga was so good that it could be stored for decades. To the Indians in general and Hindus in particular, Ganga is more than a river - it is the Holy Mother - saviour and benign. Bathing in its water washes away all sins, and a single droplet of its water relieves the humans from the eternal cycle of birth and rebirth. Today, River Ganga is still held in

reverence but treated with contempt. On several occasions during the year, millions of people congregate for bathing at different places in R. Ganga unmindful of the water quality that has deteriorated rapidly. I present here briefly the state of River Ganga and its landscape in a limnological perspective, as an example of the rapid degradation of the water quality and aquatic biological resources due to various human activities in the river basin and direct interference with the river itself.

River Ganga

River Ganga (often known as Ganges) rises in the outer Himalaya as R. Bhagirathi at 4100 m altitude from Gomukh at the base of Gangotri glacier. It is named R. Ganga only after it is joined 187 km downstream at Devprayag (500 m) by R. Alaknanda which rises from Satopanth (7010 m) west of Gangotri (Fig. 1). After flowing southwest through the hills for another 70 km, R. Ganga emerges from the mountains onto the plain at Rishikesh (348 m). Then it flows south and later southeast meandering across the plain for about 1680 km until it again turns south at Farakka. R. Ganga now bifurcates into two streams: one (named R. Bhagirathi or R. Hooghly) flows southwards through India for 470 km before meeting the Bay of Bengal at Sagar island, and the other flows southeast (now named R. Padma) into Bangladesh before meeting R. Brahmaputra at Golaundo and forming the vast delta. The lower 240 km stretch of R. Ganga in India is influenced by the tides. Along its course, R. Ganga is joined by many large tributaries. River Yamuna, the largest tributary (1376 km long), also arises in the Himalaya from the Yamunotri glacier (6320 m above m.s.l.) and flows almost parallel to R. Ganga until its confluence with the latter at Allahabad. R. Yamuna itself is joined by another major tributary, R. Chambal, which arises from the Vindhyan ranges (Central India) and drains a large area lying on the south and west of R. Yamuna (Fig. 1). Other tributaries originate in Nepal Himalaya, and include Rivers Sarda, Ghagara, Gandak, Kosi, Ramganga, Gomti, and Burhi Gandak. R. Mahananda rises from Darjeeling hills, flows south and meets R. Ganga inside Bangladesh. A few tributaries such as Rivers Tons, Son and Punpun arise in the eastern part of Vindhyan ranges and flow northward before joining R. Ganga on its right.

Compared to the R. Amazon, River Ganga is relatively small (Table 1). It's length is less than half that of Amazon, and its drainage basin is only about one-seventh of that of Amazon. The drainage basin of R. Ganga lies in the subtropical zone, almost wholly north of the Tropic of Cancer whereas the Amazon river basin lies on both sides of the Equator and wholly within the tropics. The climate in the Ganga basin is largely subtropical and is greatly influenced by the monsoon winds. The summer temperature rises above 40 °C in most of the basin but the winter temperature approaches freezing point only in the hills. The annual rainfall, of which more than 80 % is received during May to September, varies from more than 1600 mm in the east to less than 400 mm in the west. The flow in river Ganga is derived mainly from the rainfall but the snowmelt during the summer from glaciers and high Himalayan peaks makes it a perennial river. The catchments of the tributaries of R. Ganga receive more rain than that of Ganga, and hence the tributaries contribute more flow to the river. Seasonally the flow varies by more than an order of magnitude (Fig. 2). The total annual flow discharged through R.

Table 1: Comparative features of R. Ganga and R. Amazon (Data from SIOLI 1984, and CBPCWP 1984).

	R. Ganga	R. Amazon
Origin	Gangotri glacier in Himalaya	Andes mountains
Altitude at origin, m	4100	4500
Length, km	2525	6518
Width, km	1.5-2.0	4-5
Depth, m	6-8	40-50
Basin Coordinates	22 N to 31 N; 73 E to 90 E	17 S to 5 N; 79 W to 46 W
Basin area, sq.km	1060,000	7050,000
Total Annual flow	369 x 10^9	5519 x 10^9
Slope (lower reaches)	1:24,000	1:100,000
Discharge, $m^3 s^1$	11700	175,000
Sediment load, ton yr^-	4.68 x 10^8 (1250 mg/L)	2.8-13.0 x 10^8 (50-235 mg/L)
Main tributary	R. Yamuna	R. Negro

Ganga into the Bay of Bengal is only about 8 % of the flow of R. Amazon whose basin receives an annual average rainfall of over 2300 mm. Whereas in the Amazon basin 54 % of the precipitation is derived from the evapotranspiration from the basin itself (SALATI & MARQUES 1984), in the Ganga basin all of the precipitation is derived from the water vapours transported from the oceans by the monsoon winds.

Most of the Ganga basin itself had been formed by the pre-Tertiary alluvial debris from the peninsula, and Upper and post-Tertiary alluvium from the Himalaya. The soils in the basin are mostly alluvial and generally rich in calcium. The soils in the southern part of the basin are derived from the geologically very old rocks of the Vindhyan ranges whereas in the western part soils are saline and alkaline. The differences in the geology and soils of the Yamuna river basin, which constitutes the western and southern part of the Ganga basin, is reflected in the slightly dark coloured water of R. Yamuna compared to the crystal clear water of R. Ganga. The contrast becomes apparent at their confluence at Allahabad and reminds one of the similar contrast seen at the confluence of R. Solimões and R. Negro at Manaus.

Despite its small catchment area and flow, R. Ganga is only next to R. Amazon in the amount of sediments carried annually to the oceans. The high sediment load in R. Ganga (5-7 times of that in R. Amazon) and all other Himalayan rivers is largely because the Himalayan ranges, being geologically the youngest, are highly prone to erosion. This also reflects intensive human activity and extremely poor forest cover in the Ganga River basin. The erosion rate of the Ganga basin at Calcutta is 549 t/km^2/yr - about three times more than that of R. Amazon basin (SUBRAMANIAN et al. 1987). River Brahmaputra which joins Ganga just before meeting the sea, brings far more sediments and together with Ganga forms the world's largest delta that also supports the world's largest and most magnificent mangrove system.

Though the slope of the river bed in its lower reaches (1:24000) is almost as small

as that of R. Amazon, the flood amplitude and duration are not so large as that of R. Amazon. During the monsoon, the river rises by 3 to 8 m flooding the areas on both sides for several days but the flood recedes soon.

Human activities

As mentioned earlier, Ganga river basin has been the theater of one the world's oldest civilisations where human activities have continued for several millennia. Varanasi on the banks of R. Ganga is the oldest living city - in existence for more than 3000 years. Today, the basin supports more than 300 million humans and 200 million cattle and other domestic animals. More than 200 large and small towns lie on the banks of R. Ganga and its tributaries. Whereas 80 % of the Amazon river basin is occupied by pristine rainforests, the Ganga river basin has less than 10 % area under forests which occur mostly in the hills in its northern and southern parts. The floodplain forests that occurred in the foothills only in the recent past, have all disappeared almost completely (ANONYMOUS 1982; CBPCWP 1984).

The Ganga basin is highly fertile and agriculture has been the main human occupation here since historic times. To meet the needs of water for irrigation, river regulation was started several centuries ago. The waters of R. Ganga and R. Yamuna were diverted in the late 18th and 19th century through the Upper Yamuna Canal (1789), Western and Eastern Yamuna Canals (1810), Upper Ganga Canal (1854), Lower Ganga Canal (1868), and Sone Canal (1879). The Upper Ganga Canal withdraws practically all water from R. Ganga near Haridwar, soon after its descent onto the plains. Since independence, river regulation (construction of barrages and levees) has been greatly accelerated for irrigation, and flood control to protect settlements and agriculture (for details, see GOPAL 2000). All tributaries of the Ganga River system are heavily dammed and channelised. The construction of a barrage at Farakka, before the River Ganga enters Bangladesh, had until recently been a matter of dispute between the two countries. Another dam under construction on R. Ganga (R. Alaknanda) at Tehri has been of great concern to the environmentalists, particularly because of its location in a zone of high seismicity. The extensive withdrawal of water has resulted in reduced flows, often to the extent that the rivers remain dry in several stretches during the summer season. River Ganga which was used for regular ferry service from Calcutta to Allahabad, and River Yamuna which was also used for navigation from Allahabad to Agra until 1940, are no more navigable.

Urban and industrial growth has, however, made a major impact on the river water quality through the discharge of untreated domestic sewage and industrial effluents. Sewage collection and treatment facilities do not exist in most of the urban centers. Even in the large cities such as Delhi, the capital of India, only a part of the sewage receives some treatment before its discharge into the River Yamuna. Though legislative measures were taken as early as 1974 to require treatment of industrial effluents, large quantities of industrial effluents receive only a partial treatment. The impacts of wastewater discharge are aggravated by greatly reduced flows during most part of the year. In several areas, many tributaries of R. Ganga have virtually turned into sewers.

Intensive agriculture with extensive use of agrochemicals (fertilizers and pesticides), wide-spread deforestation, intensive grazing, and other anthropogenic activities further contribute to the degradation of water quality. During the rainy season, runoff from the catchments carries huge quantities of silt, nutrients and various pollutants.

Limnological characteristics: Water quality

For centuries there has been great interest in the unique property of Ganga's water, particularly from its source, that it can be stored for decades without losing its quality but studies on the chemical or biological characteristics of Ganga were not made until the middle of the last century. Sedimentological studies have shown that the water chemistry of R. Ganga is controlled by the carbonates of the recent alluvium. Illites and kaolinite are dominant clay minerals in suspended sediments, and (Ca+Mg)/(Na+K) ratio is high (SUBRAMANIAN 1979, SUBRAMANIAN et al. 1987). Studies on water chemistry, phytoplankton and fish of River Ganga were first made at Calcutta, Allahabad, and Varanasi (HAMILTON 1822; BISWAS 1940; ROY 1949, 1955; DUTTA et al. 1954; CHAKRABARTY et al. 1959, LAKSHMINARAYANA 1965, RAY et al. 1966). Several reports during the 1970s and early 1980s drew attention to the pollution of R. Ganga and rapid deterioration of water quality (CBPCWP 1984). In 1985, the Government of India launched a Ganga Action Plan to improve water quality by taking measures for sewage diversion and treatment in major cities along River Ganga. Simultaneously, limnological studies were taken up in several research centers. These studies have been summarised by BILGRAMI (1988) and KRISHNAMURTHI et al. (1991). Whereas the earlier studies focused on the riverine system for fisheries, post-1970 studies are concerned generally with the assessment and monitoring of water quality. The Central Pollution Control Board now regularly monitors the water quality in R. Ganga and its tributaries based on physico-chemical and bacteriological parameters. Functional aspects of the river ecosystem and the interactions of the river with its floodplain have received no attention.

Physico-chemical characteristics of water have been analysed at many stations along the entire stretch of the river. The water quality declines rapidly in the middle stretch (Kanpur-Allahabad-Varanasi) as the river receives huge quantities of domestic and industrial wastes (Table 2). In the lower stretch the water quality improves primarily due to dilution by the tributaries. During the past 50 years or so since independence, the water quality has degraded rapidly throughout the river length, with increase in the concentration of all elements (JHINGRAN 1989). For example, at Varanasi, the nitrate-N concentration had increased from 0.01 mg/L in winter of 1957 to 2.48 mg/L in the winter of 1981 (LAKSHMINARAYANA 1965, CWC 1987). Domestic wastes from increasing concentration of human populations in the entire basin continue to find their way into the river. In 1985, the Government launched a Ganga Action Plan to restore water quality of the river by providing sewage treatment plants in all major cities and by also enforcing the effluent standards for all industries in the river basin (ANONYMOUS 1985). However little attention has been paid to the tributaries, including R. Yamuna (see GOPAL & SAH 1993) which continue to receive untreated or partly treated domestic and industrial effluents. These efforts have therefore resulted in only minor improvement in some stretches. Recent reports on BOD values and coliform counts show that the river Ganga has instead become polluted right up to the source (CPCB 1996).

River biota

Unlike R. Amazon, the total biodiversity in the Ganga is relatively low. The phytoplankton species richness varies considerably but the zooplankton diversity is quite low. The species richness and abundance of both zooplankton and phytoplankton declined

considerably between 1950s and late 1980s due to increasing levels of organic and toxic pollutants. Earlier studies in the middle stretch of the river reported a dominance of diatoms with the green and bluegreen algae taking second and third position (LAKSHMINARAYANA 1965; RAY et al. 1966) but the studies during late 1980s recorded a steep decline in the diatoms and the dominance of green and bluegreen algae (KRISHNAMURTI et al. 1991). The zooplankton are dominated throughout the river in the plain by rotifers and protozoa. The benthic macroinvertebrate diversity however increased during the same period (JHINGRAN 1989).

The fish diversity increases from the headwaters to the estuarine zone. There are very few endemic species. The fish fauna in the mountainous stretch of the river is characterised by a few typical coldwater species such as snowtrouts and mahseers (*Schizothorax* sp., *Tor tor, Tor putitora* and *Labeo dera)*. Increasing silt load due to extensive deforestation is a major problem affecting the fisheries in this region. In the middle stretch (in the plain), the dominant fish include major carps (*Labeo rohita, Cirrhinus mrigala, Catla catla*), catfishes (*Osteobagrus* species, *Wallago attu*), *Pangasius pangasius, Bagarius bagarius* etc. The estuarine zone supports a larger variety of fishes which include freshwater (*Labeo calbasu, Mystus aor, Rita rita, Wallago attu*), brackishwater (mullets and clupeids) and marine species (*Tenuolosa ilisha, Trichiurus* sp., *Ilisha elongata, Coilia* sp.). The estuarine region is also very rich in prawn fisheries (species of *Penaeus, Metapenaeus, Palaemon*).

Whereas repeated withdrawal of water from the R. Ganga and its tributaries has intensified the levels of pollution despite some measures for wastewater treatment, extensive regulation of the rivers by dams, barrages and levees has fragmented the habitat of many important fauna. An example of these impacts is the rapid decline in the distribution and populations of Hilsa (*Tenuolosa ilisha*) which is the commercially most important fish in Indian rivers (JHINGRAN 1991). The construction of Farakka barrage, for maintaining flow in the Hooghly estuary for the Calcutta Port, has greatly impacted on Hilsa fisheries. On one hand the barrage checked fish migration upstream, and on the other, the increased freshwater discharge into the Hooghly lowered the salinity considerably affecting the fishes (CHAKRABORTY & CHATTOPADHYAY 1989; DE et al. 1989; JHINGRAN 1989). Similarly, the habitat fragmentation, besides pollution, has caused large decline in the populations of turtles, tortoises and crocodiles (SINHA 1995) and Ganges dolphin (*Platanista gangetica*), the only mammal in the river, - now an endangered species (SINHA et al. 2000).

As mentioned earlier, there is no natural floodplain vegetation left in the Ganga river basin. Large areas of floodplain have already been cut off by levees. The remaining riparian areas as well as the river bed exposed during the low water period are brought under cultivation. Most of the oxbows and other shallow waterbodies have been converted to fishponds or are in different states of degradation.

The Holy Ganga has already been turned into "unholy" river with several of its tributaries turning into drains. With the continuing growth of human population, urbanisation and globalization, the chances for the Ganga to become "holy" once again are rather bleak. Luckily, the mighty Amazon may never be tamed but it is hoped that its floodplain would not become urbanised enough to seriously threaten the water quality and its rich biodiversity.

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Table 2: Changes in water quality along the course of River Ganga (main stream) during summer season (March-June) of 1982 (data from CWC 1987) at sampling stations upstream of the town (from CWC 1987).

Parameter	Rishikesh	Garh	Fatehgarh	Kanpur	Allahabad	Mirzapur	Varanasi	Patna	Mokameh	Farakka
Distrance, km (from source)	242	434	670	800	1050	1190	1279	1532	1630	1923
Conductivity, FS	186	252	289	377	419	458	468	400	399	339
pH	8.2	8.0	8.5	8.2	8.0	8.2	8.3	8.1	8.2	8.2
Ca, mg/L	20.4	25.6	25.8	29.2	29.4	28.8	28.8	25.8	27.4	27.6
Mg, mg/L	6.3	9.3	10.1	16.0	15.6	18.5	15.5	17.3	16.5	15.4
Na, mg/L	2.8	8.5	6.9	14.0	18.4	19.3	21.4	15.6	16.3	12.4
K, mg/L	0.19	5.9	5.5	5.8	5.8	4.3	5.5	4.3	4.7	4.3
CO_3, mg/L	7.5	3.3	6.9	9.3	9.1	7.8	11.1	4.5	5.1	11.4
HCO_3, mg/L	95.2	116.5	140.9	189.7	190.3	208.6	172.6	187.3	180.6	170.8
Cl, mg/L	10.3	9.2	11.3	14.9	23.4	29.4	30.8	23.4	25.2	15.2
F, mg/L	1.33	0.19	0.19	0.19	0.4	0.4	0.38	0.38	0.19	0.19
SO_4, mg/L	6.7	22.1	24.0	20.6	29.8	40.3	42.2	23.1	31.2	20.6
NO_3, mg/L	0.0	2.5	1.9	2.5	1.2	1.9	1.9	1.2	1.2	0.6
Silicate, mg/L	14.8	8.4	6.3	7.7	6.9	6.2	7.7	7.4	7.7	6.1

Nitrites and phosphates were only in traces at all the sites.

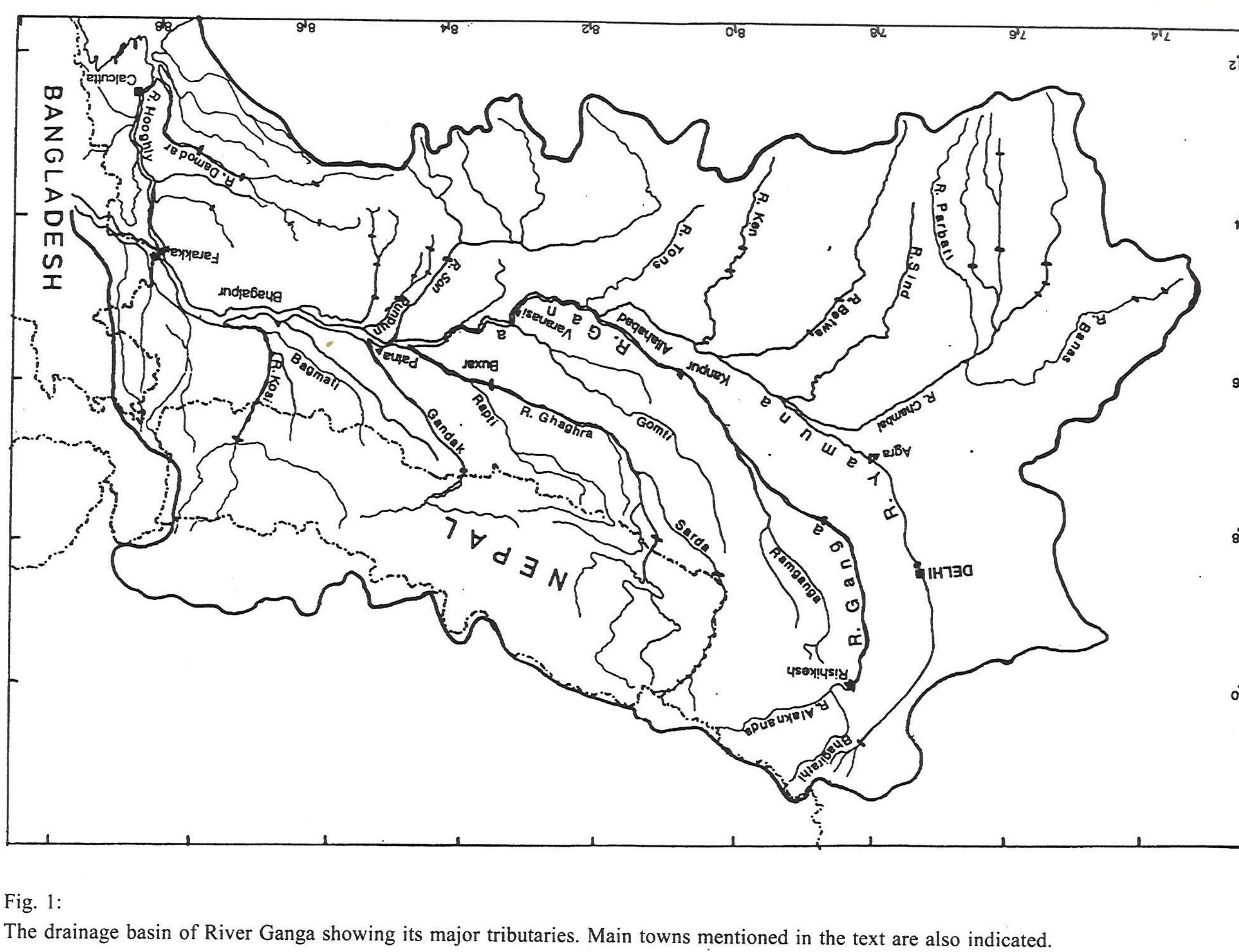

Fig. 1:
The drainage basin of River Ganga showing its major tributaries. Main towns mentioned in the text are also indicated.

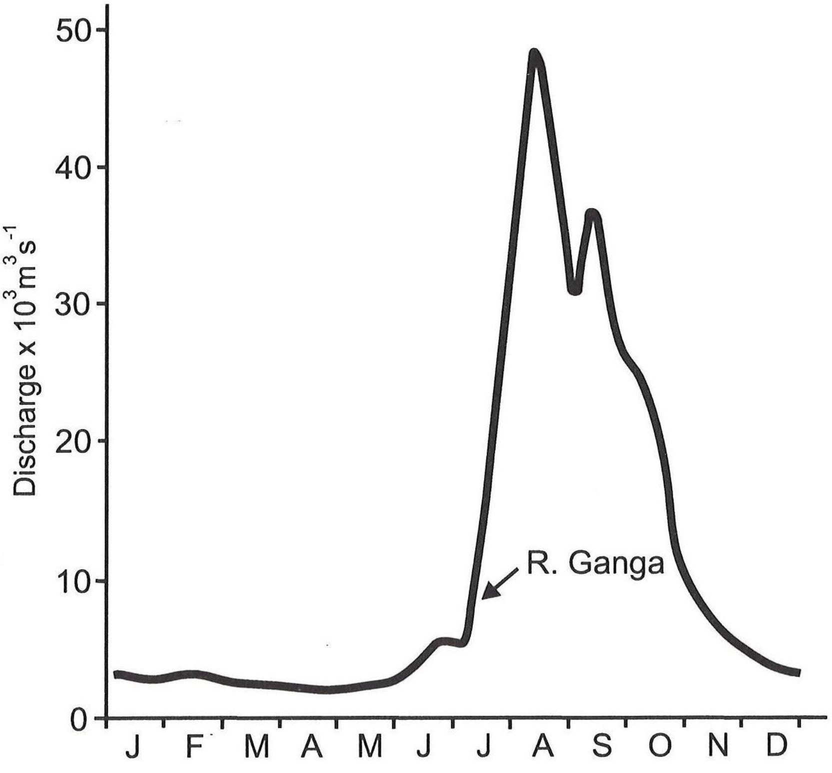

Fig. 2:
Hydrograph of River Ganga.